BOW LAKE

LAKE LAY MONITORING PROGRAM

1984

Freshwater Biology Group (FBG)

University of New Hampshire

Durham

by

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LLMP

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PREFACE

The repot begins with a non-technical, comprehensive summary. The summary is intended to provide a quick reference to the main findings of the study. The reader is referred to **Appendix** B and the glossary for a clarification of technical terms and concepts.

ACKNOWLEDGMENTS

The Lake Lay Monitoring Program was established on Bow Lake in the fall of 1983. Through the direction of Mr. Charlie Palm and Dr. Steve Steinmuller summer testing began in 1984. Lay monitors on Bow Lake were: Charlie Palm, G. Palm, B. Palm, R. Sawyer and S. Kemp.

We congratulate the lay monitors on the quality of their work and their dedication to the program, and anticipate that the monitors will continue their efforts next year. The LLMP would like to thank Mr. Palm, Dr. Steinmuller all the members of the Bow Lake Association for their time and efforts in coordinating and managing the LLMP at Bow Lake. Also, we would like to thank the members of the association who provided boats for our field team.

Members of our Freshwater Biology Group included Kim Babbitt, Matt Boyle, Chris Brown, Emily LeViness, Deb Thunberg and Jennifer Turner. Kim was team leader, and was responsible for coordination of field trips and data analysis and interpretation. Matt was responsible for phosphorus analysis, Chris for chlorophyll a analysis, Emily for phytoplankton, and Deb for zooplankton. All team members helped with data organization and filing, and also with field trips throughout the summer. In the fall, Sara Hubner helped with word processing and report organization.

The final report was assembled on computers. Much of the software is available on the Charybdis DEC-10 computer at the University of New Hampshire. The main programs we used were 1022, a data management system (Digital Electronic Corporation); RUNOFF, an Australian word processing program; MINITAB (Pennsylvania State University), a statistics package; and UPLOT (Professor A. L. Baker, author), a plotting package. Final graphs were plotted on the CALCOMP drum plotter available on the DEC-10 Charybdis computer. The Office of Computer Services kindly provided computer time and data storage space for the Lake Lay Monitoring Program. The final text was set with Wordstar on Northstar and Zenith microcomputers, and printed on a letter-quality Spinwriter.

INTRODUCTION

This report presents the findings of the 1984 summer study of Bow Lake. The study was conducted jointly by the Freshwater Biology Group (FBG), University of New Hampshire, and the Bow Lake Association, as part of the Lake Lay Monitoring Program (LLMP). The LLMP is a long-term water quality monitoring program that relies heavily on the efforts of lay persons. In Durham, the LLMP is conducted by Dr. Alan L. Baker (Associate Prof. of Botany) and Dr. James F. Haney (Associate Prof. of Zoology), who direct a team of trained graduate and undergraduate students. Space and research facilities were provided by the Departments of Botany and Zoology at the University of New Hampshire. Secretarial services were provided by the Department of Zoology.

The LLMP is a cooperative effort between the FBG and cooperating lake associations, conservation commissions, and municipalities. Funding for the program is derived solely by contributions from the participating groups. During 1984, the participating groups included: Walker Pond Protection Association, Town of Hollis, Town of Hudson Town of Merrimack, Town of Amherst, Lake Chocorua Association, Lake Winnipesaukee Association, United Associations of Alton, Long Island Landowner's Association, Squam Lake Association, Merrymeeting Lake Association, Silver Lake Association (Madison), Bow Lake Association, Kanasatka Lake Association, Canaan Street Lake Association, Sunset Lake Association, and Wentworth Lake Association.

The LLMP has two major goals: first, to carry out scientific investigations on participating lakes in order to provide a data-base on lake biology, physics, and chemistry; and second, to educate people about lakes and their management. A broad data-base on lakes is necessary for their proper management, but is often lacking. Through the efforts of lay monitors and FBG members, such a data-base can be provided. This commitment is long-term due to the long period of time it may require a lake to exhibit signs of disturbance. Continued monitoring from year to year is essential for the early detection of changes in lake conditions.

Education is also an important goal of the LLMP. Through education, people's awareness of lakes and human activities that may influence lakes is heightened.

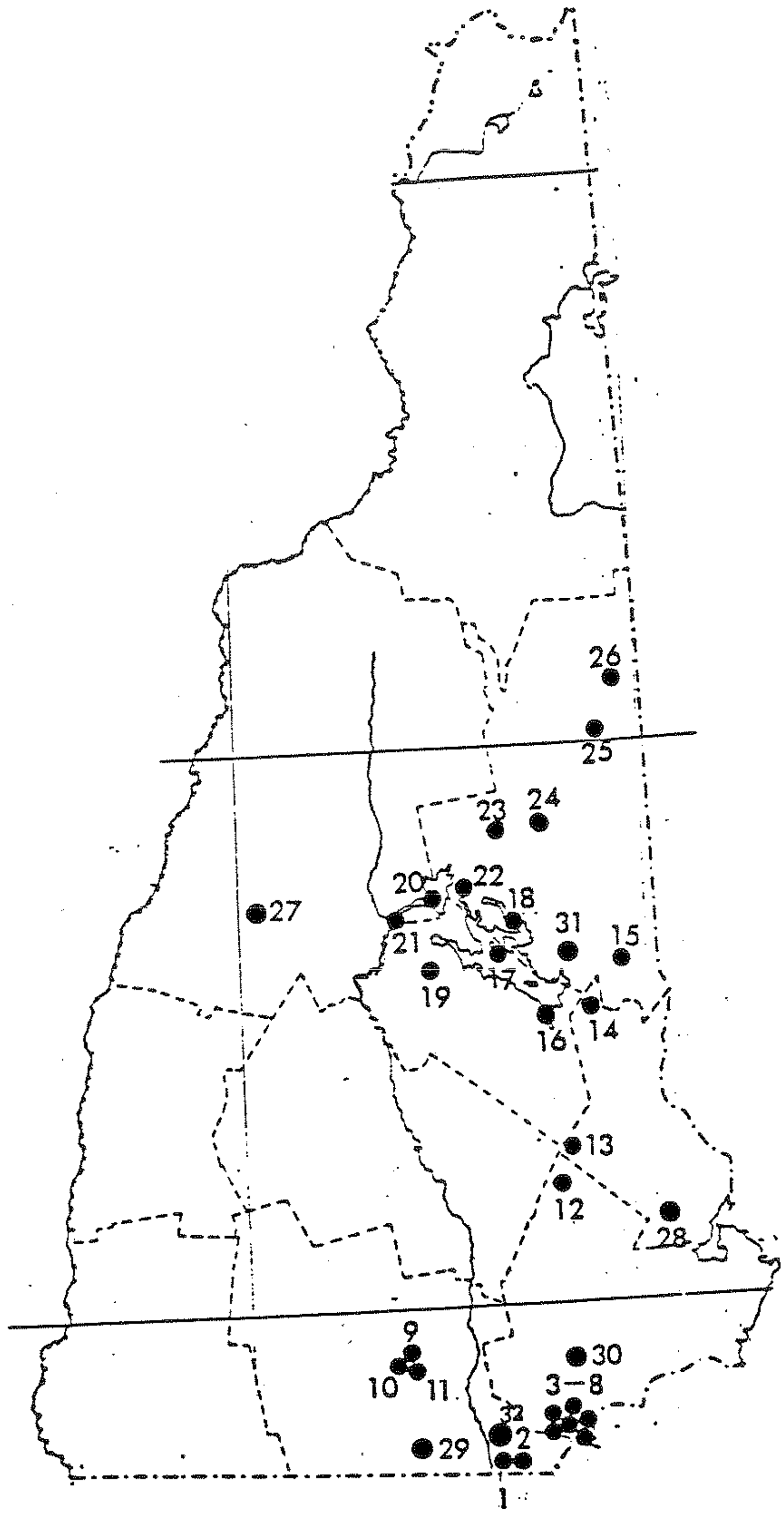

Figure 1. Map of New Hampshire. The locations of lakes in the LLMP in New Hampshire are indicated by closed circles. [Key to lakes is located on the next page.]

Key to lakes involved one or more years with the LLMP:

Map location	Lake	Town	Numbers of observations: FBG	Lay Monitors
16	Alton Bay*	Alton Bay	6	142
3	Arlington Mill	Salem	22	78
11	Baboosic	Amherst, Merrimack	19	86
23	Bearcamp	Sandwich	7	86
13	Bow	Strafford	4	7
27	Canaan Street	Canaan	--	12
4	Canobie	Salem	15	29
8	Captain's	Salem	--	8
25	Chocorua	Tamworth	9	29
26	Conway	Conway	7	46
10	Horseshoe	Merrimack	4	14
22	Kanasatka	Moultonboro	--	48
28	Lamprey (river)	Lee	12	--
21	Little Squam	Holderness	17	113
17	Long Island*	Moultonboro	2	165
15	Lovell	Wakefield	2	--
32	Merrill Brook	Hudson	25	--
14	Merrymeeting	New Durham	12	78
5	Millville	Salem	10	84
18	Moultonboro Bay*	Moultonboro	31	237
9	Naticook	Amherst, Merrimack	4	18
1	Ottarnic	Hudson	14	43
12	Pleasant	Deerfield	6	80
2	Robinson	Hudson	13	107
6	Shadow	Salem	9	17
24	Silver	Madison	4	129
29	Silver	Hollis	4	23
20	Squam	Holderness	21	514
30	Sunset	Hampstead	--	13
31	Wentworth	Wolfboro	1	17
19	Winona	Center Harbor	4	4
7	World's End	Salem	--	12
		Total:	274	2208

* Sections of Lake Winnipesaukee include Alton Bay, Long Island and Moultonboro Bay.

Brief Non-technical Summary

1) Bow Lake is oligotrophic (high water quality) based on high water clarity (Secchi disk depth), low concentrations of algae (chlorophyll a) and low total phosphorus concentration.

2) pH values below 6.0 were found throughout the water column in June, and below 8.0 meters in August. Values below 5.5-6.0 may be harmful to the growth and distribution of fish. Alkalinity values (buffering capacity) were very low, an indication that Bow Lake has a low ability to resist the effects of acid rain.

3) The data collected by the lay monitors and the Freshwater Biology Group represents a good beginning of a long-term data base for Bow Lake. With such a data base, comparisons can be made from year to year and changes in lakewater quality can be detected early.

Comments and Recommendations for Bow Lake 1984

1) Data collection by lay monitors should be increased next year. Variations in trophic indicators (Secchi disk depth, chlorophyll a and total phosphorus) occur throughout the summer period. In order to monitor these variations properly, data should be collected throughout the entire summer (June-August). Without a full season of data, interpretations about lakewater quality are difficult to make.

2) A program of lay monitor alkalinity (buffering capacity) and pH testing should be initiated to assess the effects of acid precipitation on the lake. It is important to establish a data base for alkalinity and pH in order to detect changes in these parameters as early as possible. This could be accomplished by training at least one lay monitor on the use of the pH meter and the chemical test for alkalinity. A workshop on "Testing for the Effects of Acid Precipitation" will be offered by the Freshwater Biology Group at the University of New Hampshire in late May or early June.

3) One phosphorus sample collected by the FBG was moderately high. Samples should be collected by lay monitors next year. Sampling should be done in the spring and after storm events, when inputs of phosphorus are likely to be greatest.

4) To provide data on changes in water color throughout the season, we suggest lay monitors collect samples for dissolved water color. Water color decreases the water transparency, and thus effects the Secchi disk depth. A more accurate assessment of water quality based on Secchi disk depth can be made by knowing both the chlorophyll _a_ concentration and the amount of dissolved water color. Water color samples consist of the filtrate from the chlorophyll _a_ sample, and sampling can be done with essentially no additional cost. Details on the method for collection of dissolved water color samples will be provided on request.

Executive Summary for Bow Lake 1984

1) Bow Lake is oligotrophic based on Secchi disk depth (lay data avg. 6.1 meters) and chlorophyll a concentration (lay data avg. 1.4 milligrams per cubic meter), and total phosphorus concentration (avg. 8.3 micrograms per liter). Note, however, that the highest total phosphorus concentration found (14.0 micrograms per liter) approaches the mesotrophic range. The density of phytoplankton was low to moderate (1640-3162 cells per liter), an indication of oligotrophic conditions. The Chrysophyceae (*Ochromonas*, *Chrysochromulina*) were dominant over the entire summer. The density of zooplankton was also low (5-7 animals per liter). The calanoid copepods were dominant in June, and in August *Bosmina*, *Diaphanosoma* and calanoid copepods were co-dominant.

2) Near-surface pH values ranged from 5.4-6.6. pH values below 6.0 were found throughout the entire water column in June and below 8.0 meters in August. Values below 5.5-6.0 may be detrimental to the growth and distribution of fish. The alkalinity was very low (1.8 milligrams calcium carbonate. The low level of alkalinity indicates that Bow Lake has a low ability to resist the effects of acid precipitation.

3) Dissolved oxygen concentrations were above 7.0 ppm throughout the entire water column in June. Hypolimnetic dissolved oxygen concentrations fell below 4.0 ppm August. Values below 4.0 ppm may limit the growth and distribution of cold-water fish, such as lake trout or land-locked salmon.

4) The specific conductivity was low, with an average of 28.5 micromhos per centimeter. These values were among the lowest in the LLMP. Chloride ion concentration was also low with an average of 0.5 parts per million. These values indicated low inputs of road salt and/or raw sewage.

METHODS OF LAY MONITORS

Lay monitors collected data on three parameters: thermal stratification, water clarity, and chlorophyll a concentration. Data were collected at weekly intervals whenever possible.

Thermal profiles were obtained by collecting lakewater samples at several depths with a modified Meyer bottle (Lind, 1979). Samples were obtained by lowering the empty but weighted bottle and sampling (by pulling out the stopper) at 1-meter intervals. The temperature of the samples was measured with Taylor pocket thermometers, and recorded in degrees Celsius.

Water clarity was measured while lowering an 8-inch (20 cm) Secchi disk and holding a view-scope just below the surface to eliminate the effects of surface reflection and wave-action. When the Secchi Disk disappeared the depth mark on the plastic suspension line was noted. The disk was raised until it just came into sight, and again the depth on the line was noted. The process was repeated two to three times, and an average between the two marks on the line (the point of disappearance and the point of re-appearance) was considered to be the Secchi Disk Depth (SDD), measured to the nearest one-tenth meter (0.1 meter) -- as for example, 5.2 meters. Readings were generally taken between 9 a.m. and 3 p.m., the period of maximum light penetration.

Chlorophyll a concentration was used as an estimator of algal biomass. A weighted tube 33 feet (10 meters) in length was used to collect an integrated water sample from the 'upper-lake' (epilimnion). The weighted end of the tube was slowly lowered to the interface of the epilimnion and the 'middle-lake' (metalimnion). The end of the tube was then bent double to shut off flow of air and water, and the weighted end of the tube (presently at the base of the epilimnion) was pulled up to the surface with a plastic line attached to it. The water in the tube (epilimnetic lakewater sample) was poured into a plastic bottle by placing the weighted end of the tube into the neck of the bottle and, while keeping the bent-off end above the weighted end, unbending the upper end (allowing the sample to discharge into the bottle).

Water samples were filtered through a membrane filter with a porosity of 0.45 microns. The damp filters containing chlorophyll-bearing algae were air dried for at least 15 minutes to prevent decomposition. Filtration and drying were done in the shade to minimize destruction (by bleaching) of chlorophyll. The dried filters were then sent to UNH for analysis. [In Durham, members of the Freshwater Biology Group extracted chlorophyll in 90% acetone saturated with magnesium carbonate, and read the absorbance of the sample at standard wavelengths (663 and 750 nanometers).

METHODS OF FRESHWATER BIOLOGY GROUP (FBG) TEAM

The same as well as additional parameters were investigated by the FBG research team. The additional factors were primarily measurements of sunlight penetration into the lakewater, and water chemistry. The latter included dissolved oxygen, 'free' (unbound) carbon dioxide, pH, specific conductivity, chloride ion, and total phosphorus. In addition, the microscopic plants (phytoplanktonic algae) and animals (zooplanktonic invertebrates) were identified. Relative or absolute counts were made.

Dissolved oxygen and temperature were measured with a Yellow Springs Instruments Model 54A Oxygen/Temperature meter with a submersible probe. Readings were taken at 1-meter intervals throughout the 'upper-lake' (epilimnion) and 'lower-lake'(hypolimnion), and at half-meter intervals through the 'middle-lake' (metalimnion).

Sun- and skylight penetration into the lakewater was measured at 1-meter intervals with a Whitney submersible photometer model LMA-8A, and the relative light intensity was recorded. Measurements were taken on the sunny side of the boat.

Dissolved water color was measured by reading the absorbance of filtered lakewater (0.45 micron) at 440 and 493 nanometers, in a Bausch and Lomb Spectronic 710 with a 15 cm path length.

Water chemistry (alkalinity, 'free' (unbound) carbon dioxide, pH, and specific conductivity and chloride ion) samples were collected with a 3-liter Van Dorn bottle. Alkalinity, free carbon dioxide and pH samples were stored on ice in 250 ml polyethylene bottles, and were analyzed in the field within 1 to 2 hours. Specific conductivity and chloride ion samples were analyzed in the lab, at room temperature.

Alkalinity was determined titrimetrically with 0.002 N sulfuric acid to a final pH of 4.5, with a combination solution of the two dyes bromocresol green and methyl red as the end-point indicator (E.P.A.,1979). Alkalinity is expressed as equivalents of calcium carbonate.

Free (unbound) carbon dioxide concentration was determined by titrating the fresh lakewater samples with 0.0027 N NaOH to a final pH of 8.3, and with the dye phenolphthalein as the end-point indicator.

Lakewater pH was measured with a digital pH meter (Orion model 231) equipped with a combination probe (Orion Co.).

Specific conductivity was measured with a Barnstead Conductivity Bridge Model PM-70CB equipped with model B-10 probe (cell constant = 1.0). Correction for sample temperature was made with a standard curve.

Chloride ion concentration was measured with a pH meter (Corning Model 10) equipped with a chloride electrode (Orion model 94-17B) and a double junction reference electrode (Orion Model 90-02). Standard curves were prepared every 2 hours during laboratory analysis.

Samples to be analyzed for total phosphorus, phytoplankton, and chlorophyll *a* were collected with a vertical 'tube' sampler. Chlorophyll *a* samples were filtered, dried and analysed in the same manner as those collected by lay monitors.

Total phosphorus samples were stored on ice in acid-washed 250 ml polyethylene bottles, and were fixed within 1 to 2 hours with 1.0 ml concentrated sulfuric acid. In Durham, the FBG members digested the total-phosphorus by adding ammonium persulfate and auto-claving the samples for at least 45 minutes. Finally, the phosphorus content of the samples was analyzed with the single-reagent method that included a fresh solution of ascorbic acid and potassium antimony tartrate (E.P.A., 1979). Absorbance of the blue phosphorus complex was measured spectrophotometrically at 650 nm.

Phytoplankton samples were fixed with iodine (Lugol's Solution) in the field, within 1 to 2 hours after collection. Phytoplankton were counted with a Unitron 'inverted' microscope after settling the samples for 24 hours in counting chambers. At least 200 individual algal 'units' were counted with a modified scan technique (Baker, 1973).

Zooplankton density was estimated in samples collected by towing up a plankton net (30 cm diameter, 150 micron porosity) through the oxygenated (>0.5 ppm) portion of the lake. Samples were fixed after collection with a 4% formalin-sucrose solution (Haney and Hall,1973), and subsampled with a 1-ml Hensen-Stemple pipet. Sufficient subsamples were taken to insure that at least 100 microcrustaceans were counted.

RESULTS AND DISCUSSION OF LAY MONITOR DATA

Lay monitor research was conducted separately from Freshwater Biology Group (FBG) research, thus the results are presented separately. Two sampling sites were established on Bow Lake (Fig. 2). The lay monitor raw data for 1984 are presented in Appendix A.

Lay monitors collected information on three parameters: water transparency (Secchi disk depth), productivity (chlorophyll a), and thermal stratification. Information on thermal stratification is used primarily to determine the sampling depth of the chlorophyll a sample.

Figure 2. Bow Lake, Town of Strafford, New Hampshire.
Outline map and location of 1984 sampling sites.

Secchi Disk Depth (Lay monitor)

The water clarity on Bow Lake was high, with an average of 6.1 meters, and a range 5.4-6.9 meters. Seasonal patterns were similar at both sites, with lowest transparency in early August and highest in late August (Fig. 3).

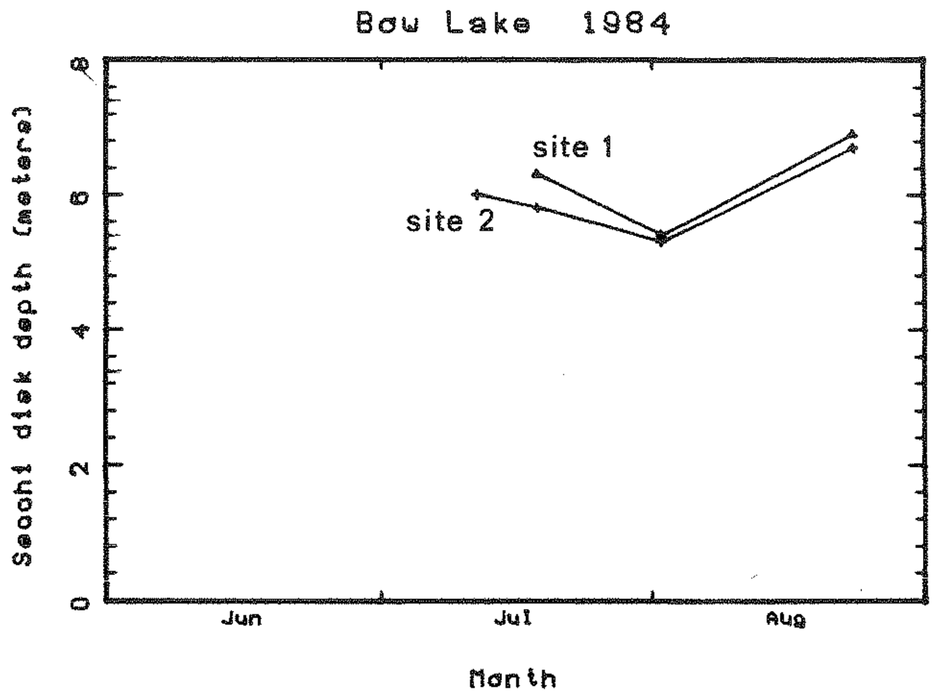

Figure 3. Seasonal variation of Secchi disk depth.

Chlorophyll a (Lay monitor)

Chlorophyll a concentrations were in the range 1.0-2.3 milligrams per cubic meter, with an average 1.4 milligrams per cubic meter. The highest chlorophyll a concentration was found at site 3 in mid-July. Seasonal trends in chlorophyll a concentration were not apparent (Fig. 4).

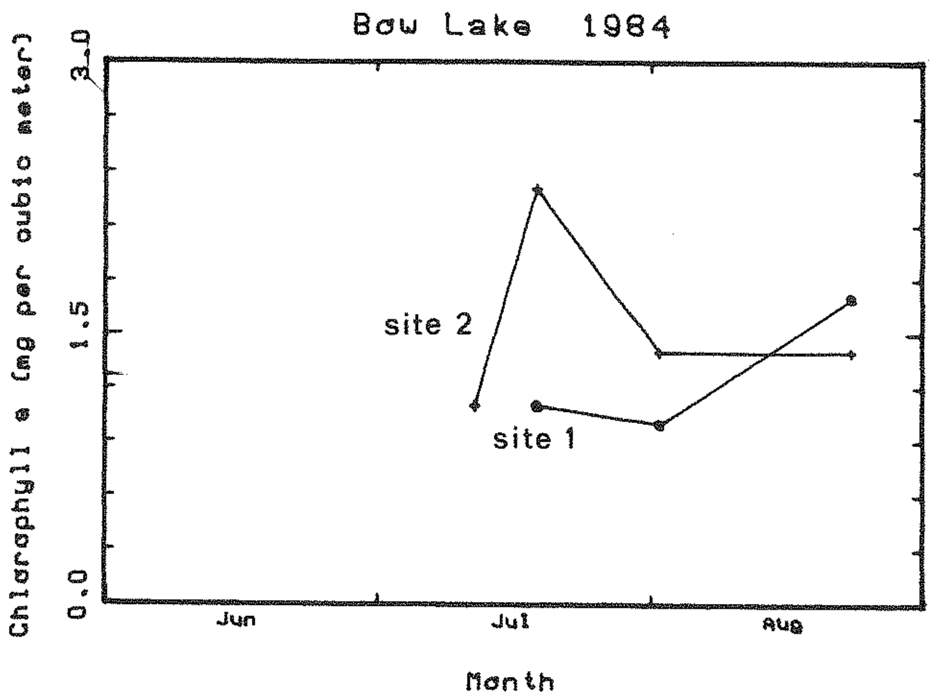

Figure 4. Seasonal variation in chlorophyll a concentration.

Discussion of Lay Monitor Data

Bow Lake is oligotrophic based on deep Secchi disk depth and low chlorophyll a concentration. Compared to other lakes in the LLMP, the water clarity at Bow is relatively high and chlorophyll a concentration relatively low (Figs. 5 & 6).

Because this is the first year of lay monitoring on Bow Lake, no comparisons can be made with previous lay data. The New Hampshire Water Supply and Pollution Control Commission measured a Secchi disk depth of 5.5 meters and a chlorophyll a concentration of 3.2 milligrams per cubic meter on July 31, 1978. The chlorophyll a value is higher than any observed by the lay monitors or the LLMP, but because it is a single value, it has little comparative value.

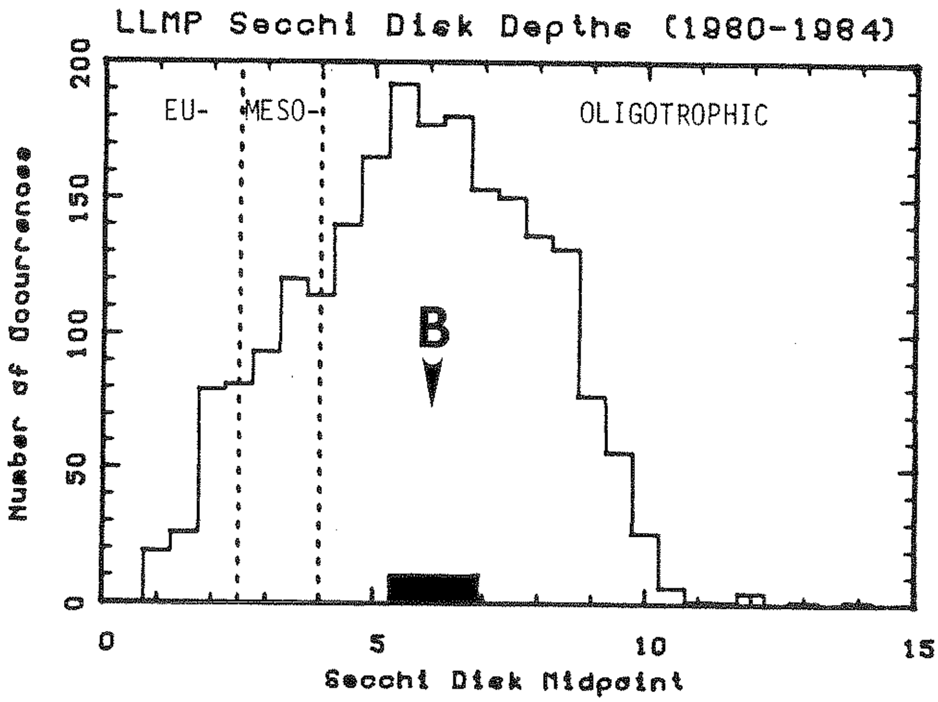

Figure5. Frequency distribution of Secchi disk depth. Arrow indicates mean and bar indicates range of values for Bow Lake.

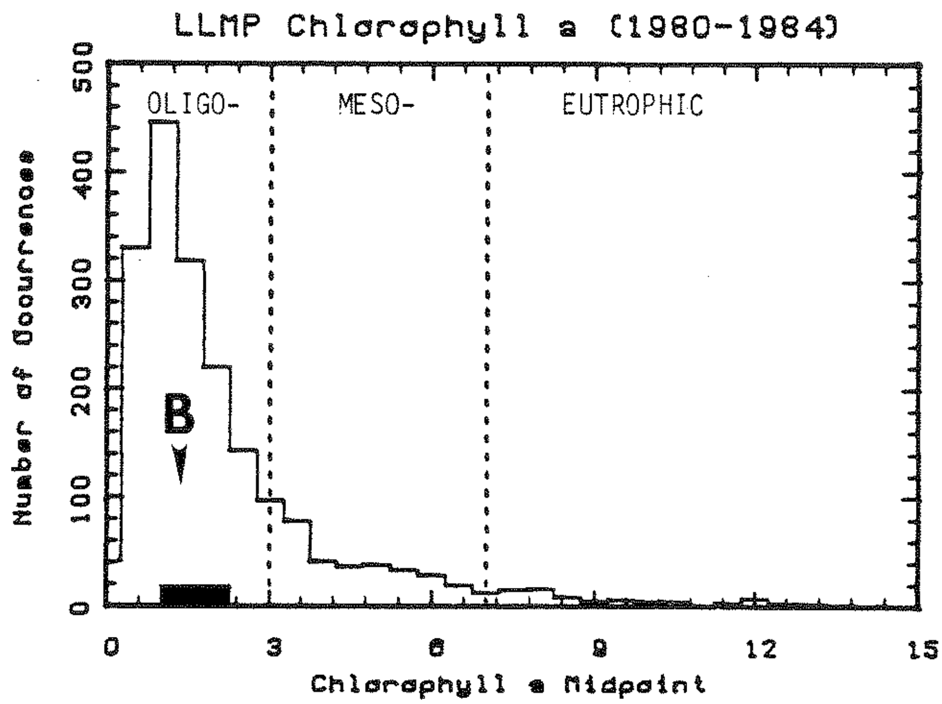

Figure 6. Frequency distribution of chlorophyll a. Arrow indicates mean and bar indicates range of values for Bow Lake.

RESULTS AND DISCUSSION OF FRESHWATER BIOLOGY GROUP DATA

Temperature and Dissolved Oxygen (FBG)

Bow Lake was thermally stratified on all three FBG test dates (Fig. 7). Dissolved oxygen concentration was high (above 7.0 ppm) throughout most of the water column in June. Hypolimnetic oxygen concentrations fell below 4.0 ppm at both sites in August (Fig. 8). Concentrations below 4.0 ppm may limit the growth and distribution of cold-water fish such as lake trout or land-locked salmon. Such a decrease in hypolimnetic oxygen over the summer indicates moderate productivity.

Water Clarity and Dissolved Color (FBG)

The water clarity was high at Bow Lake, with a Secchi disk depth range 7.0-7.8 meters. Secchi disk depth increased from 7.0 to 7.6 meters at site 1, and was 7.8 meters at site 3 on both test dates (Table 1).

Dissolved water color (absorbance per 15 cm. at 440 nm.), primarily due to humic acids, decreased from .026-.007. The decrease in water color may be due to bleaching of humic acids by the sun, or a decrease of inputs in July and August. These values are relatively low compared to other lakes in the LLMP (Fig. 9). The result of having low water color in the lake is to increase light penetration in the water column. This in turn increases water clarity, and thus Secchi disk depth.

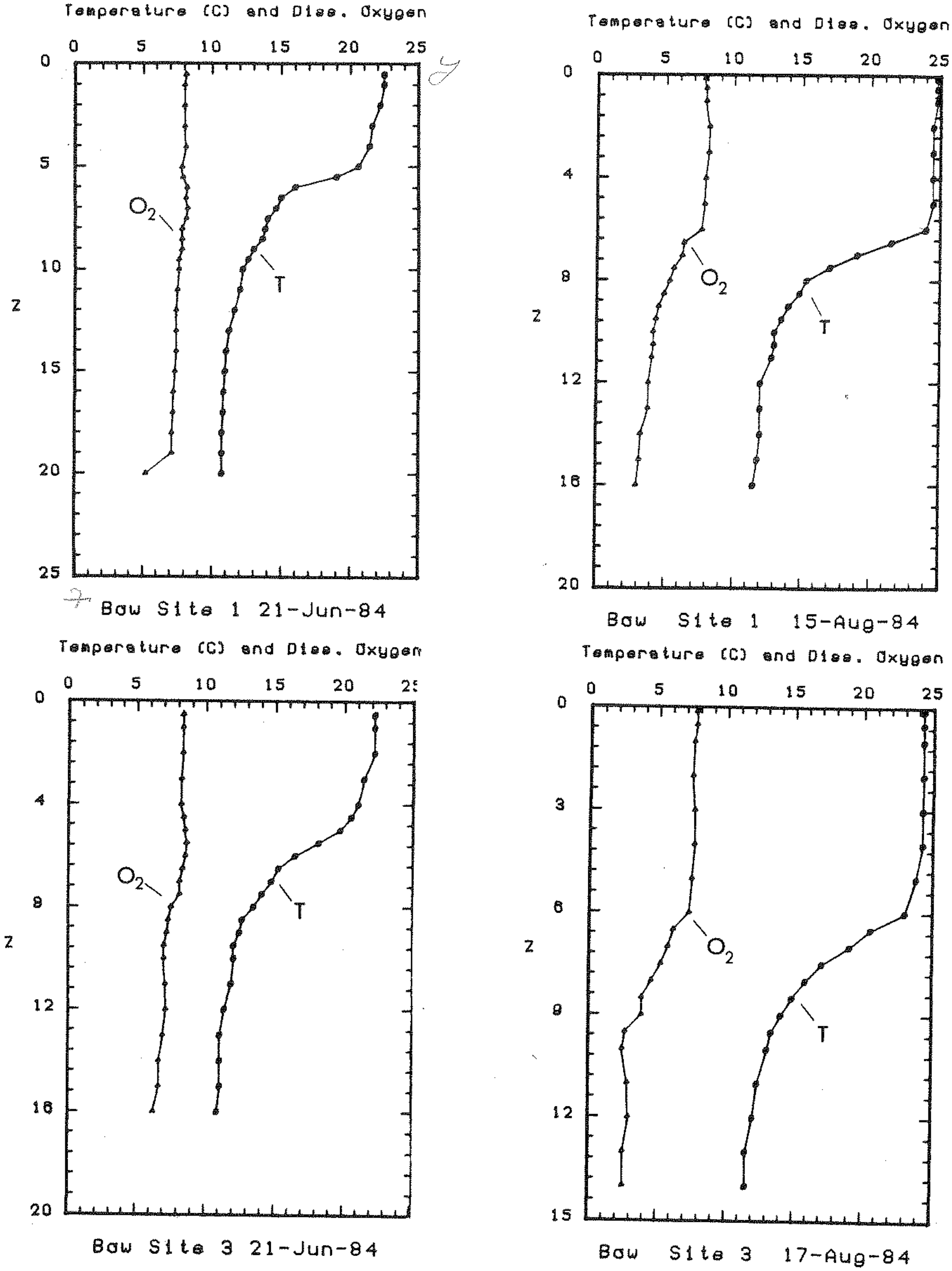

Figure 7. Temperature and oxygen profiles for Bow Lake, 1984.

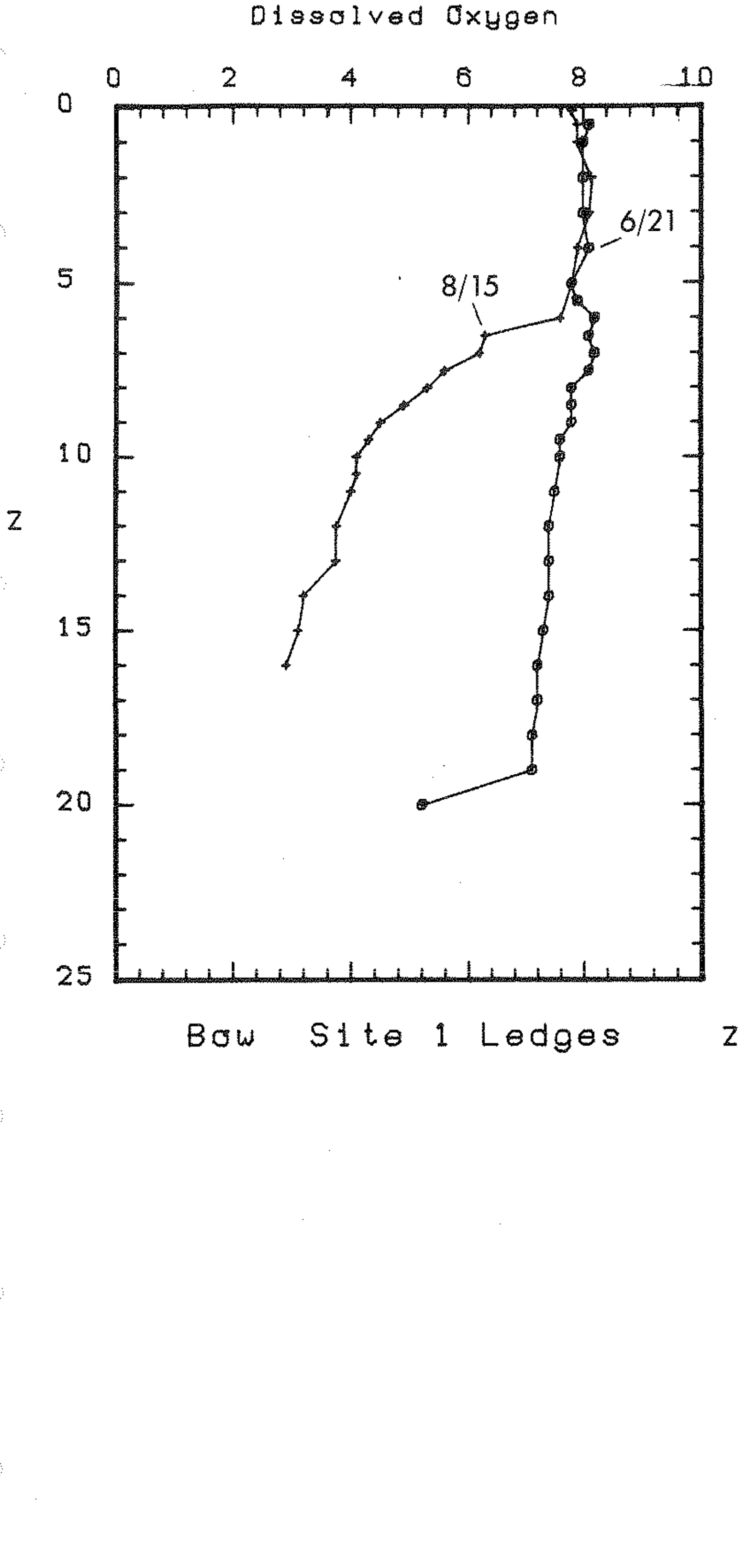

Figure 8. Dissolved oxygen profiles comparing early and late test dates.

Table 1. Comparison of Secchi disk depth (SDD) and chlorophyll a (Chl a) for 1984. (SDD=meters, Chl a=milligrams/cubic meter)

		SDD	Chl a
Site 1	June 21	7.0	1.1
	Aug 15	7.6	1.7
Site 3	June 21	7.8	1.2
	Aug 17	7.8	1.1

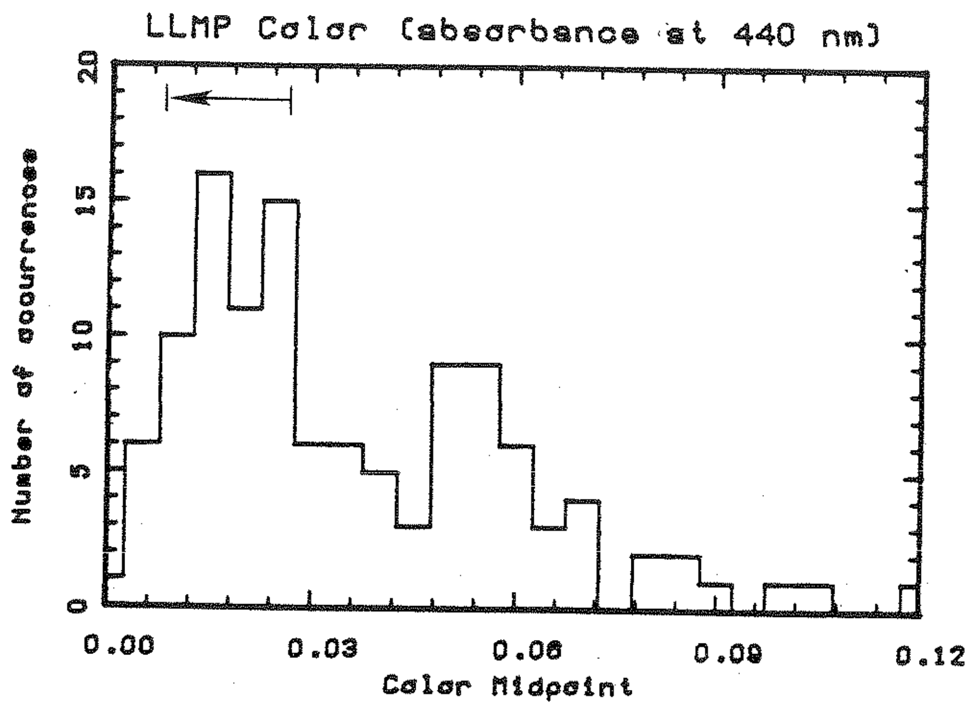

Figure 9. Frequency distribution of dissolved color of lakes in the LLMP. Arrow indicates change in color over the summer.

Chlorophyll a (FBG)

Chlorophyll a concentrations were in the range 1.1-1.7 milligrams per cubic meter, with an average of 1.3 milligrams per cubic meter (Table 1). The chlorophyll a concentration was higher in August at site 1, and did not change significantly at site 3.

Phosphorus (FBG)

Total phosphorus is usually the most limiting (least abundant) nutrient to algae in freshwater systems. Phosphorus regulates algal productivity and therefore regulates chlorophyll a concentration, and indirectly (through chlorophyll a) influences water transparency. Increases in algal growth may occur with increases in phosphorus loading. Total phosphorus values were in the range 3.0-14.0 micrograms per liter, with an average of 8.3 micrograms per liter (Table 2). Based on total phosphorus, Bow Lake would be classed as oligotrophic (Fig. 10). Note, however, that the highest concentration (14.0 micrograms per liter) approaches the mesotrophic range for phosphorus concentration.

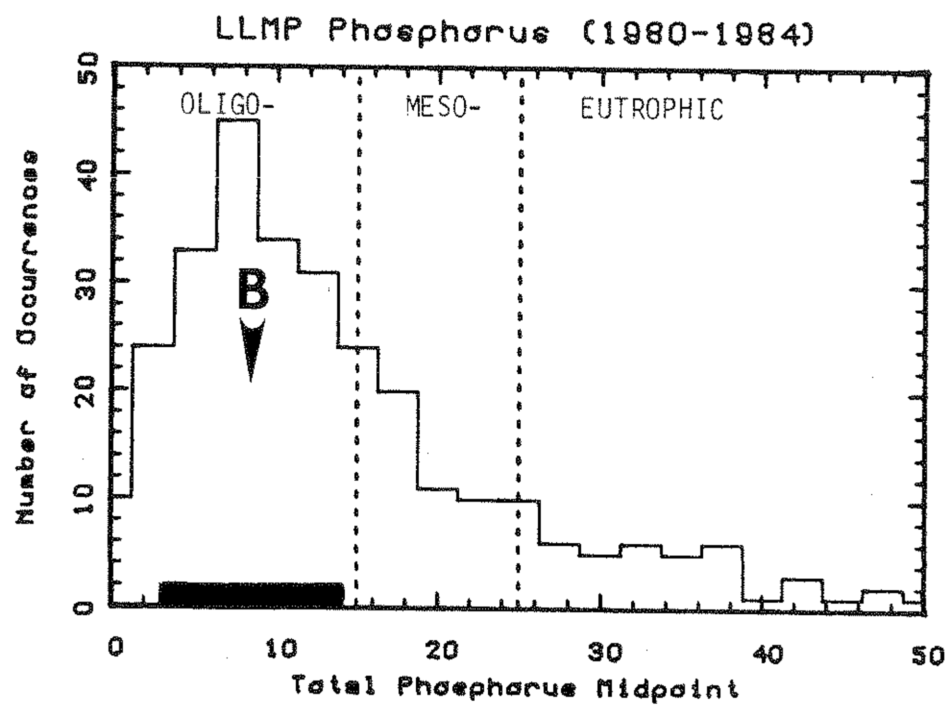

Figure 10. Frequency distribution of total phosphorus. Arrow indicates the mean, and the bar indicates the range of values from Bow Lake.

Table 2. Total phosphorus (TP) concentrations for Bow Lake, 1984. (TP=micrograms/liter)

		TP
Site 1	June 21	7.6
	Aug 15	8.4
Site 3	June 21	3.0
	Aug 17	14.0

Alkalinity, pH, and Free Carbon Dioxide

The pH of near-surface water was in the range 5.4-6.6. pH values below 6.0 were found throughout the entire water column in June and below 8.0 meters in August. Values below 5.5-6.0 may be detrimental to the growth and distribution of cold-water fish. The alkalinity of near-surface water was extremely low, with an average of 1.8 milligrams calcium carbonate. Low levels of alkalinity indicate that Bow Lake has a low capacity to resist the effects of acid precipitation. The New Hampshire Water Supply and Pollution Control Commission measured an alkalinity of 3.0 milligrams calcium carbonate on July 31, 1978. From this data it is not apparent whether the buffering capacity of Bow Lake is decreasing. The data do indicate that the alkalinity is very low and should be monitored closely in the future.

Free carbon dioxide accumulated in deep water, lowering the pH in that depth zone (Fig. 11). The small amount of accumulated free carbon dioxide is an indication of low productivity.

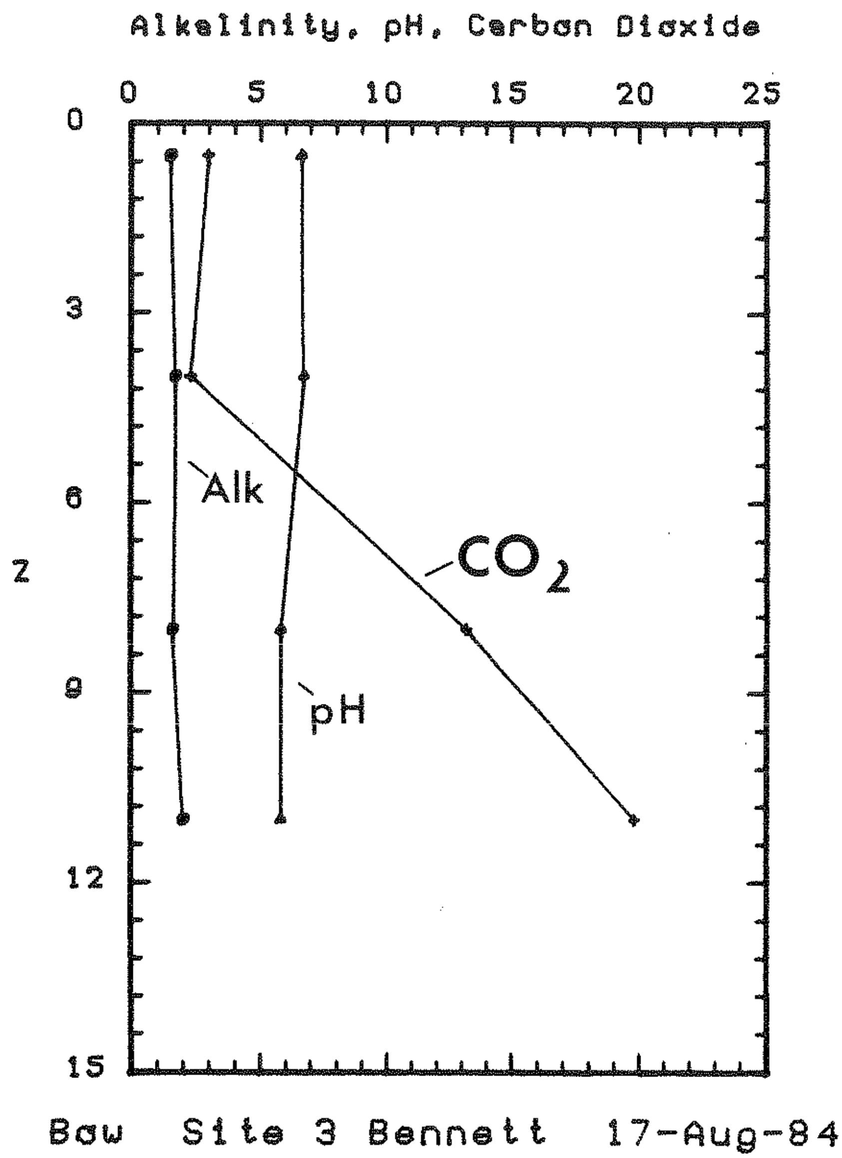

Figure 11. Profile of pH, alkalinity, and free carbon dioxide at Bow Lake, August 17,1984.

Specific Conductivity and Chloride Ion

The specific conductivity in Bow Lake was low, with an average of 28.5 micromhos/cm from all depths and all dates. Values at Bow Lake were among the lowest in the LLMP. The chloride ion concentration was also low, with an average of 0.5 parts per million. These values indicate low inputs of road salt and/or raw sewage.

Phytoplankton

The density of phytoplankton in Bow was low to moderate (1640-3162 cells per liter). The Chrysophyceae were dominant throughout the entire sampling season (Table 3, Fig 12). *Ochromonas* dominated in June, and in August dominance shifted to *Chrysochromulina*, although *Ochromonas* was still abundant. The Cryptomonads (*Chroomonas* and *Crytomonas*) and the Chlorophyceae (small green flagellates) were also important. In August, the blue-green bacteria (*Merismopedia*) were of numerical importance. The presence of blue-green bacteria usually indicates mesotrophic or eutrophic conditions, however *Merismopedia* appears to be more general in its affinities. The species concentration and composition indicates oligotrophic conditions at Bow Lake.

Phytoplankton community in Bow Lake, Strafford, NH 1984

Numbers are cells, colonies or filaments per milliliter

	Site 1		Site 3	
	21-June	15-Aug	21-June	17-Aug
Cyanophyceae				
Aphanocapsa				12
Aphanothece sp.	6	12	8	36
Chroococcus colony		6		6
Coelosphaerium sp.		6		
cf. Gleothece sp.		42		
Gomphosphaeria				6
Merismopedia sp.		60	4	102
Oscillatoria sp.	12			
Misc. colonies		6		12
Chlorophyceae				
Ankistrodesmus	12		12	
Chlamydomonas sp.	36	6	92	12
cf. Coccomonas				6
Crucigenia sp.	18	12		
Elakatothrix sp.	6			
Golenkinia sp.		6		6
Oocystis sp.	66	48	36	6
Planktosphaeria		12		
Polytomella sp.		12		6
Polytoma sp.	48	24	44	6
Sphaerocystis sp.		6	8	6
Quadrigula		12		
Unidentified green unicells		78		60
Bacillariophyceae				
Asterionella sp.	6			
Cyclotella/Stephanodiscus sp.	48	12	44	6
Tabellaria sp.	36		24	

PHYTOPLANKTON (Continued)

	Site 1		Site 3	
	21-June	15-Aug	21-June	17-Aug
Cryptophyceae				
Chroomonas cf. acuta	294	90	140	102
Cryptomonas cf. erosa	16	132	80	54
Dinophyceae				
Peridinium sp.		30		6
Unidentified dinoflagellate				6
Chrysophyceae				
Chrysochromulina sp.	30	852	4	264
cf. Chrysomoeba/Rhizochysis		54		18
Chrysosphaerella longispina	18		12	
Diceras sp.		6		
Dinobryon sp.		12	4	12
Mallomonas sp.	24	30	16	48
Kephyrion/Pseudokephyrion sp.	102		84	24
cf. Ochromonas sp.	282	396	160	450
cf. Uroglenopsis	18			
Epipyxis	36		52	
Other unidentified algae				
Unidentified, no affiliation	780	1200	628	948
TOTALS	1640	3162	2028	2232

Table 3. Phytoplankton composition and concentration at Bow Lake, Strafford, NH 1984.

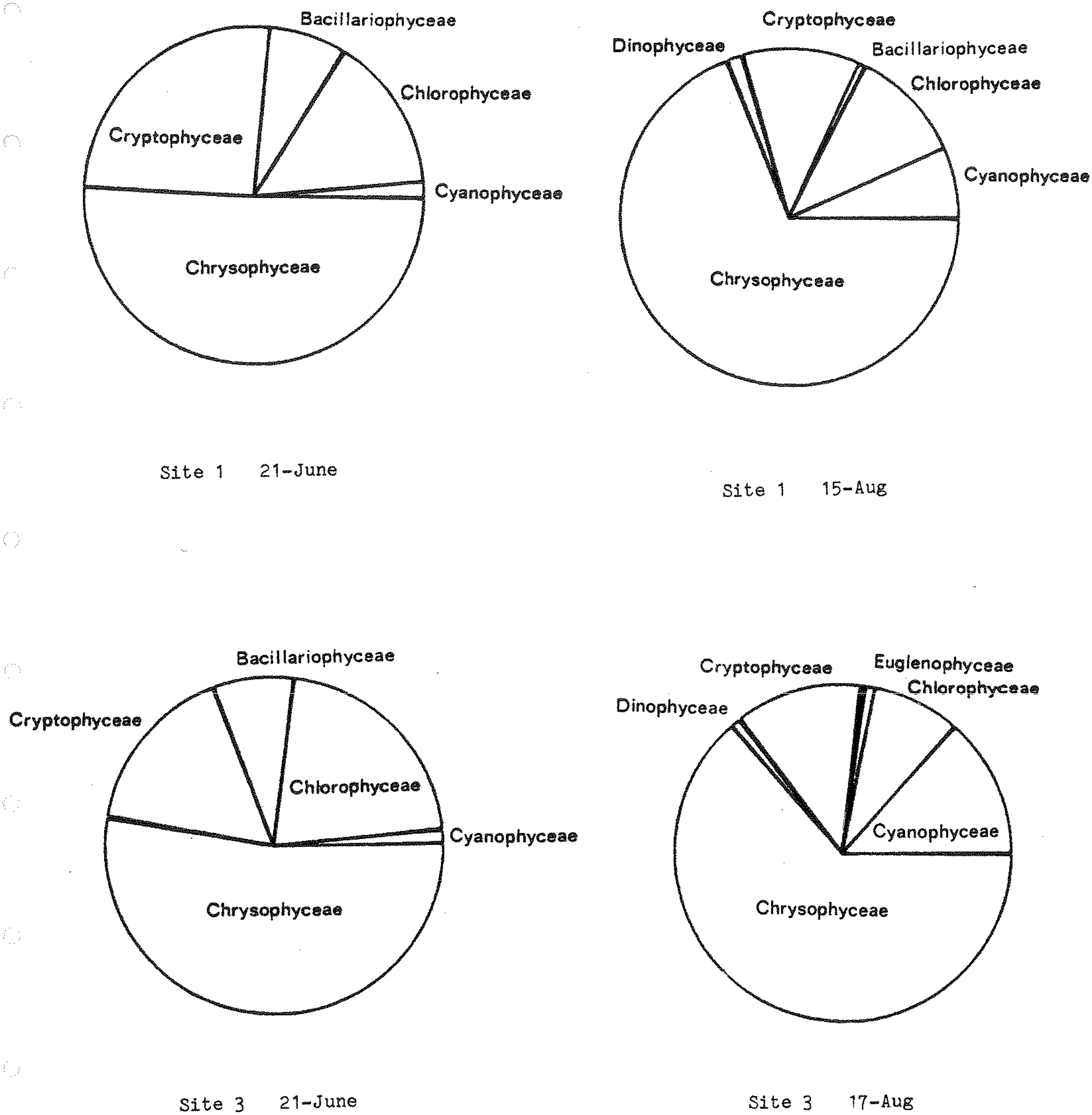

Fig 12. Change in phytoplankton composition during the summer. Pie pieces represent abundance of phytoplankton taxon relative to other taxa.

Zooplankton

The density of herbivorous crustacean zooplankton was low, 5-7 animals per liter. In June, the dominant group was the calanoid copepods (Table 4, Fig. 13). In August, Bosmina and Diaphanosoma became relatively important, although their absolute abundance was low. The low density of all the crustacean zooplankton is characteristic of oligotrophic conditions.

Zooplankton community in Bow Lake, Strafford, NH 1984

Numbers are animals per liter

	Site 1		Site 3	
	21-June	15-Aug	21-June	17-Aug
Herbivorous				
Bosmina	.106	2.62	.236	1.06
Daphnia catawba	.884	.156	.990	.033
Daphnia ambigua	.035		.047	
Daphnia sp.				.189
Diaphanosoma	.354	2.15	.330	2.24
Holopedium	.955	.312	.754	.265
Calanoid copepod	3.68	1.93	5.09	1.97
Chydorus	.035			
Predacious				
Cyclopoid copepod	.990	2.00	1.13	1.86
Polyphemus		.031		
Other				
Copepod nauplii	3.75	3.03	5.56	2.92
Chaoborus		.125		.189
Totals: Herbivorous crustacea	6.01	7.17	7.45	5.66
All Taxa	10.79	12.35	14.14	10.63

Table 4. Zooplankton composition and concentration at Bow Lake,

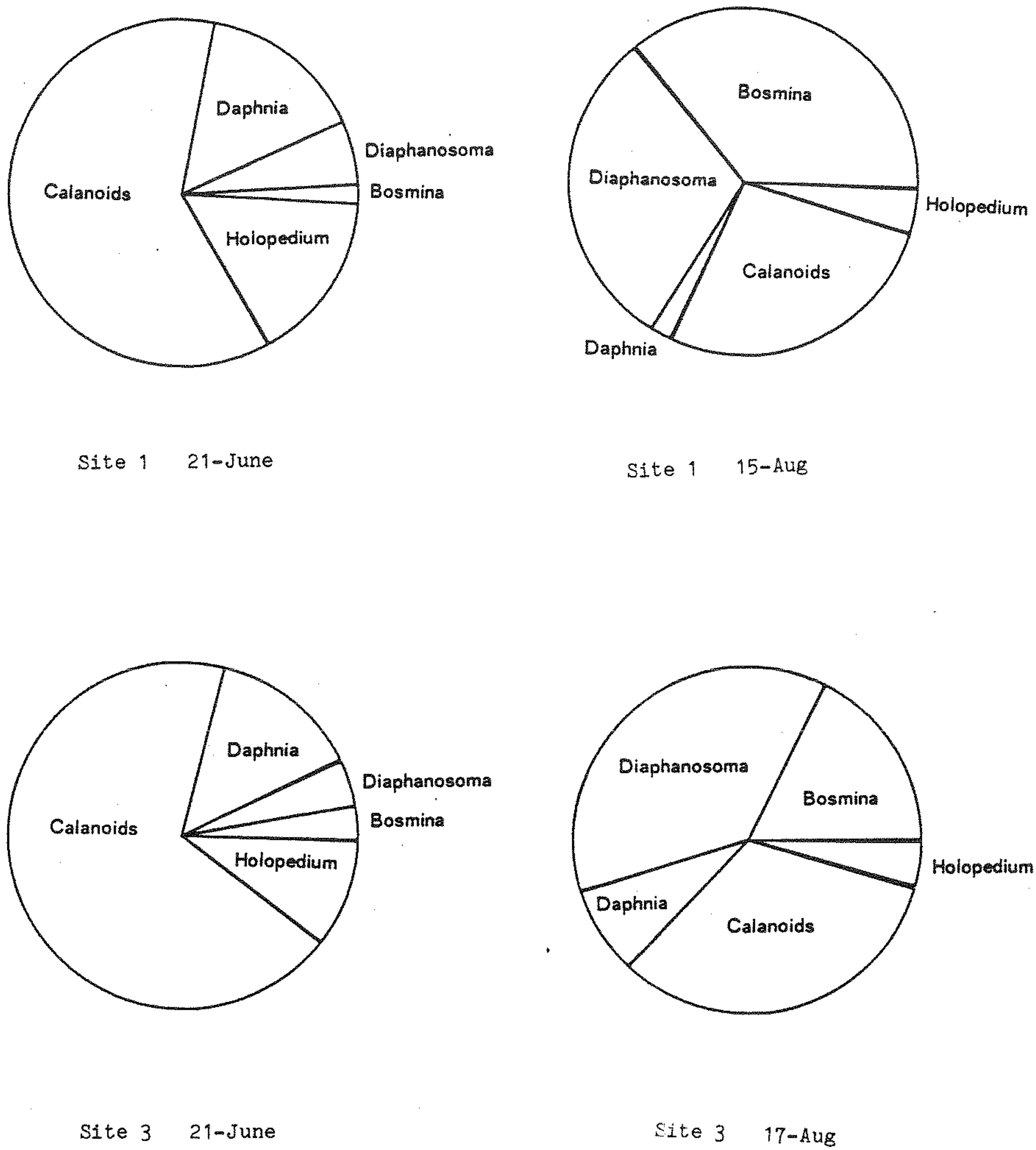

Fig. 13. Change in zooplankton abundance during the summer. Pie pieces represent abundance of each taxon relative to the other taxa.

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APPENDIX A

LLMP 1984 -- Lay Monitor Data: Bow   Jan-29-85   14:49.12

Date	Lake	Site	SDD	Chl
Jul-18-84	Bow	1 Ledges	6.30	1.14
Aug-01-84	Bow	1 Ledges	5.40	1.00
Aug-23-84	Bow	1 Ledges	6.90	1.71
Jul-11-84	Bow	3 Bennett	6.00	1.14
Jul-18-84	Bow	3 Bennett	5.80	2.28
Aug-01-84	Bow	3 Bennett	5.30	1.41
Aug-23-84	Bow	3 Bennett	6.70	1.43

>>> END OF LIST <<<

APPENDIX B

CLARIFICATION OF SOME TERMS AND CONCEPTS

Thermal Stratification

Thermal stratification as a seasonal phenomenon is of prime importance in the lives of aquatic organisms. The formation of thermal layers affects many of the chemical and physical factors of their environment.

New Hampshire lakes are generally dimictic, with mixing of the water column occurring in the spring and fall. During periods of mixing, sometimes called overturn, the entire water column tends to circulate (holomixis). That is, the bottom-most waters are refreshed with water recently in contact with the atmosphere. The surface waters are enriched with water recently in contact with the bottom sediments. Some lakes, especially those with a high salt content toward the bottom of the basin, may be meromictic and fail to mix (overturn) to the bottom.

During the spring, the entire water column ciculates freely, resuspending and redissolving material from the bottom sediments. As the sun's intensity increases, the surface waters are heated so that they become buoyant and tend to float, creating a mixing-barrier with cooler water beneath. Eventually three layers are formed, called the upper-lake (epilimnion), middle-lake (metalimnion), and lower-lake (hypolimnion) (Fig. B-1). Characteristically, the epilimnion and hypolimnion are uniform in temperature, even though the upper lake is warm and the lower lake is usually very cold. In contrast, the temperature gradually or suddenly becomes cooler in the metalimnion (sometimes called the thermocline, or temperature gradient). The gradation in temperature corresponds to a gradient in other important characteristics of water, such as viscosity and specific gravity, that explain the presence of a mixing barrier between the epilimnion and the hypolimnion.

Depth of the metalimnion through the summer is variable, and is regulated to a large extent by the length of the wind-fetch on the lake (the length of lake aligned with the predominant axis of wind-storms). In the autumn, the sun's intensity decreases, the water in the epilimnion cools, and the mixing barrier weakens. Eventually the metalimnion disintegrates and the fall overturn occurs.

Ice and snow insulate the lakewater during winter, and the liquid lakewater cools to nearly freezing just under the ice layer, while it remains relatively warm further down in the water column (about 10 degrees Fahrenheit, or 4 degrees Celsius). Sometimes the overburden of snow after a heavy snowstorm in January or February may cause melt-holes to form in the ice, and the snow may turn to slush even while the air temperature is at its seasonal coldest (as low as 25 or 30 degrees below zero Fahrenheit)! This has caused some hysteria about 'radioactive things dropping from outer space' or 'radioactive substances dropping from jet planes' -- even though it is only the weight of snow! Some reverse stratification may occur, with a layer of colder water overlying the relatively warmer water below.

Two aspects of the seasonal thermal stratification cycle about which we are most concerned are vertical mixing (overturn) and the formation of stratified temperature layers during the summer. Periods of overturn are very important because of their effect of enriching the lakewater with material from the sediments. In eutrophic lakes, blooms of algae generally follow these periods in response to high concentrations of chemicals such as phosphorus, nitrogen, silica, and other essential nutrients -- those required for the growth of microscopic algae.

Effects of stratification will vary depending upon the depth of the lake or cove. In shallow areas, the epilimnion may extend to the bottom. If this is the case, the lakewater will constantly pick up material from the bottom usually resulting in a decrease in water transparency and an increase in algal growth.

One of the major consequences of a stratified lake system is reduced transportation of material between the bottom and surface. The effects of having a "barrier" within the water column are many but the most important include transport of nutrients from the epilimnion to the hypolimnion by sedimentation (enriching the hypolimnion at the expense of the epilimnion), and oxygen depletion in the hypolimnion.

Loss of nutrients from the epilimnion is due primarily to the sedimentation of plankton organisms such as algae and bacteria. The depletion of nutrients from the epilimnion is important for restricting the growth of algae during the summer, because the primary productivity of most lakes occurs only in the epilimnion. As a result of fall overturn the surface waters may become mixed with nutrient-rich bottom waters, and fall pulses of phytoplankton (freely-drifting microscopic algae) may develop.

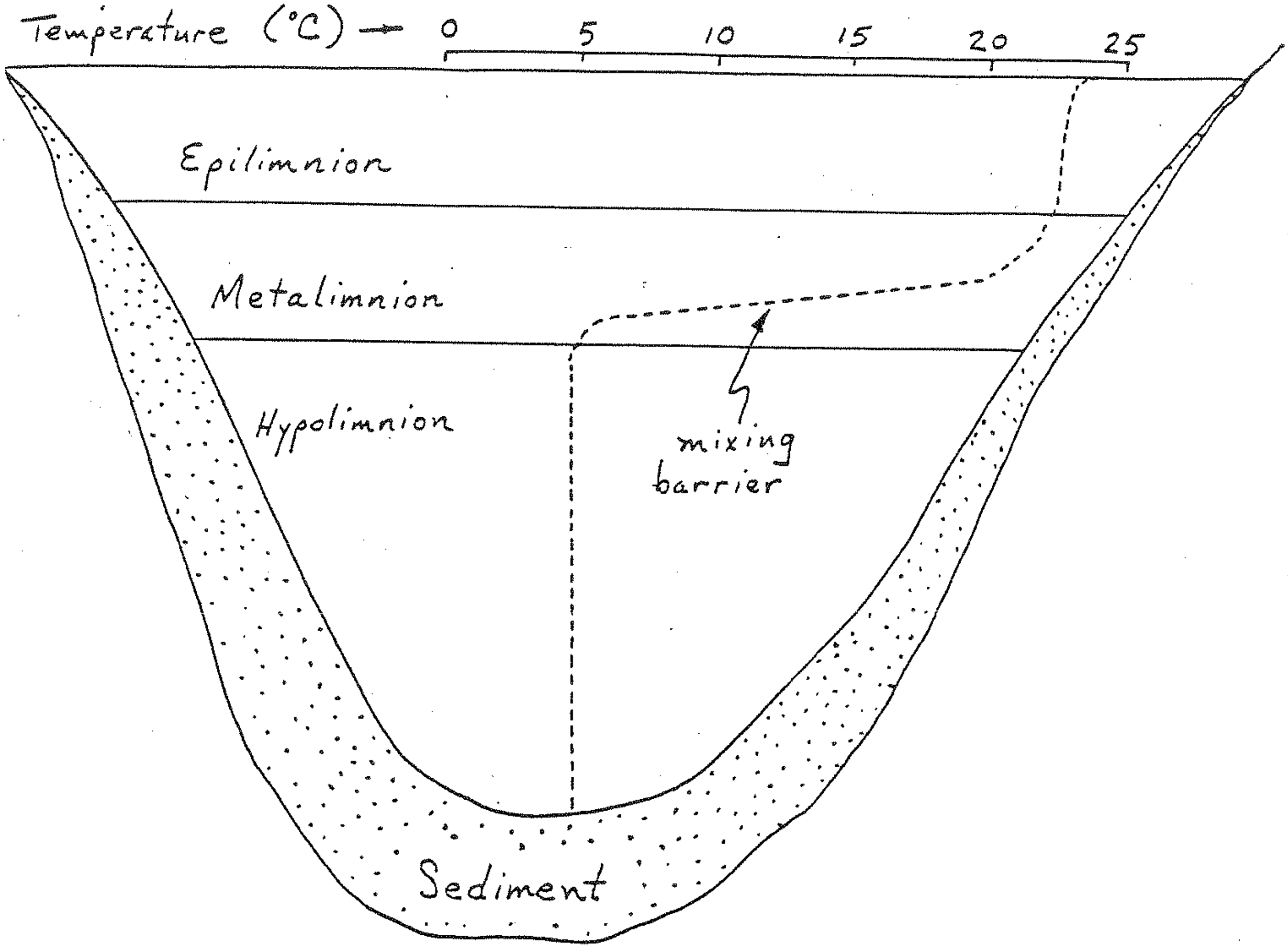

Figure B-1. Typical summer thermal stratification of a temperate lake. The 'metalimnion' provides a mixing barrier between the 'epilimnion' and the 'hypolimnion'. The dashed line represents the thermal profile, with cold water in the hypolimnion.

Oxygen Depletion

Oxygen depletion in the hypolimnion occurs for two major reasons -- respiration by plants, bacteria and animals, and absence of mixing of the water column (combined with respiration). The resultant loss of oxygen plays an important role in regulating the depth regions within which aerobic (requiring oxygen) and anaerobic (oxygen avoiding) organisms may thrive. The aerobic organisms include some bacteria, most algae, and all animals, and although they may have special adaptations to allow a tolerance to very low levels of dissolved oxygen, even for prolonged periods of time, they must occasionally obtain a supply of oxygen. The algae are the principal source of re-oxygenation by photosynthesis in the metalimnion, and the balance between oxygen production (by photosynthesis) and consumption (by respiration) is critical in determining the oxygen depletion in lakewater. The problem is minimal in surface waters, as the atmosphere overhead is a good source of oxygen. A third and generally lesser reason for oxygen depletion in water is chemical oxygen demand, that can occur when highly reduced bottom sediments are disturbed, or when a significant amount of a polluting substance with oxygen demand is dumped into a lake. (The latter should never happen, but has happened in New Hampshire!)

Fisherman are acutely aware of the oxygen requirement of fish, and know that they can expect no laketrout fishing where oxygen has been depleted in the cool bottom waters of a lake. In fact, the laketrout, as well as related species of fish, are entirely eliminated from such lakes. Even though the surface waters are well oxygenated, the temperature is too high to support the salmonid-type fish.

Most people are unaware that important groups of micro-organisms thrive in the anoxic (lacking oxygen, similar to anaerobic) bottom waters of lakes. For the most part, these are the important groups of bacteria that regulate cycles of nutrients at or near the bottom of such lakes. The bacteria are involved in crucial processes that may determine the chemical quality of the lake -- including modification of all nutrients essential to growth of the microscopic algae -- such as carbon, phosphorus nitrogen, and sulphur, by putrefaction or break-down of dead organisms, and by fermentation. The anaerobic bacteria are also involved in processes such as nitrogen fixation that converts unavailable nitrogen to very-available ammonia, and in the formation of a large host of dissolved organic substances such as vitamins that promote the growth of microscopic algae. In general, the anaerobic bacteria can be viewed as the principal agents involved in promoting recycling of essential nutrients that otherwise would have been lost and locked up in the lake sediments.

Water transparency

Water transparency, as indicated by secchi disk depth, is influenced by many factors. Dissolved substances such as humic acids (tea-colored coloring matter from plant decay) will frequently lend a yellow or brown color to the water, thus decreasing its transparency. The humic acids are especially prevalent in waters running through bogs or coniferous forests.

Another factor affecting water transparency is the number of particles suspended in the water column. Suspended particles are of two types: sediments and living organisms. Sediments are especially prevalent in areas where mixing occurs all the way to the bottom, as during overturn of holomictic lakes. Human activity such as boating or swimming can also resuspend sediments. Among living organisms, phytoplankton has the greatest effect on water transparency, due to its pigmentation and abundance. Chlorophyll a, the pigment common to all photosynthetic phytoplankton, is used as one measure of phytoplankton density.

Water transparency (measured as the Secchi Disk Depth), chlorophyll a and thermal stratification, along with other important physical, chemical and biological observations of study lakes, are the core of the lay monitoring program. Long- or short-term trends in these data can be used as indicators of changing trophic status of lakes.

Lake Trophic Status

Every classification scheme suffers from over-simplification! The very act of classifying requires the definition of classes within which study objects may be placed or pigeon-holed. Often the classes are defined by some arbitrary means, and the boundaries are subject to change depending upon the definition that is used. The fundamental problem with the process of classification is that once boundaries are set and classes are defined, we tend to think of the classes as somehow isolated from each other. Instead they may blend into each other at the boundaries. As you consider the classification scheme, please think of a continual gradient of individual lake types, through which any lake may pass. The passage may require a long period of time, given changes in the landscape or climate by natural causes, or a relatively short time given human-induced changes in use of the lake or its shoreline and watershed. One may hope that the following five categories of trophic status will help to simplify what we know about lakes, yet leave us with a sense of the probable evolution of lakes between classes of trophic status.

Three major categories of trophic status include oligotrophy, mesotrophy, eutrophy. Oligotrophic lakes characteristically have high transparency and low concentrations of chlorophyll *a* and phosphorus. Therefore, a large fraction of the visible portion of sunlight radiation, including from blue through red light, can penetrate to great depths in the lakes. Mesotrophic lakes are intermediate, and eutrophic lakes have relatively low transparency and high concentrations of chlorophyll *a* and phosphorus. Due to the high chlorophyll concentration, restrictions are placed on the transmission of sunlight into eutrophic lakes -- especially on blue and red light that are absorbed in the upper waters of the lakes by microscopic algae. Generally green light penetrates furthest into such lakes, and although it can be used in photosynthesis, it is less efficient than red or blue light. Thus photosynthesis is more restricted to upper layers in eutrophic lakes than in less-productive lakes.

Of major importance in determining lake trophic status is the difference in the rate of change of chlorophyll concentration, and therefore usually the change in secchi disk transparency, during the summer months. Such changes are slight in oligotrophic lakes, but abrupt and significant in mesotrophic and eutrophic lakes (Fig. B-2). Thus the frequency of sampling must be accelerated in more productive lakes, in order to define the times of change in chlorophyll and other parameters. Even the weekly frequency of sampling is insufficient for fully defining the changes in eutrophic lakes, while such sampling is quite effective in oligotrophic lakes.

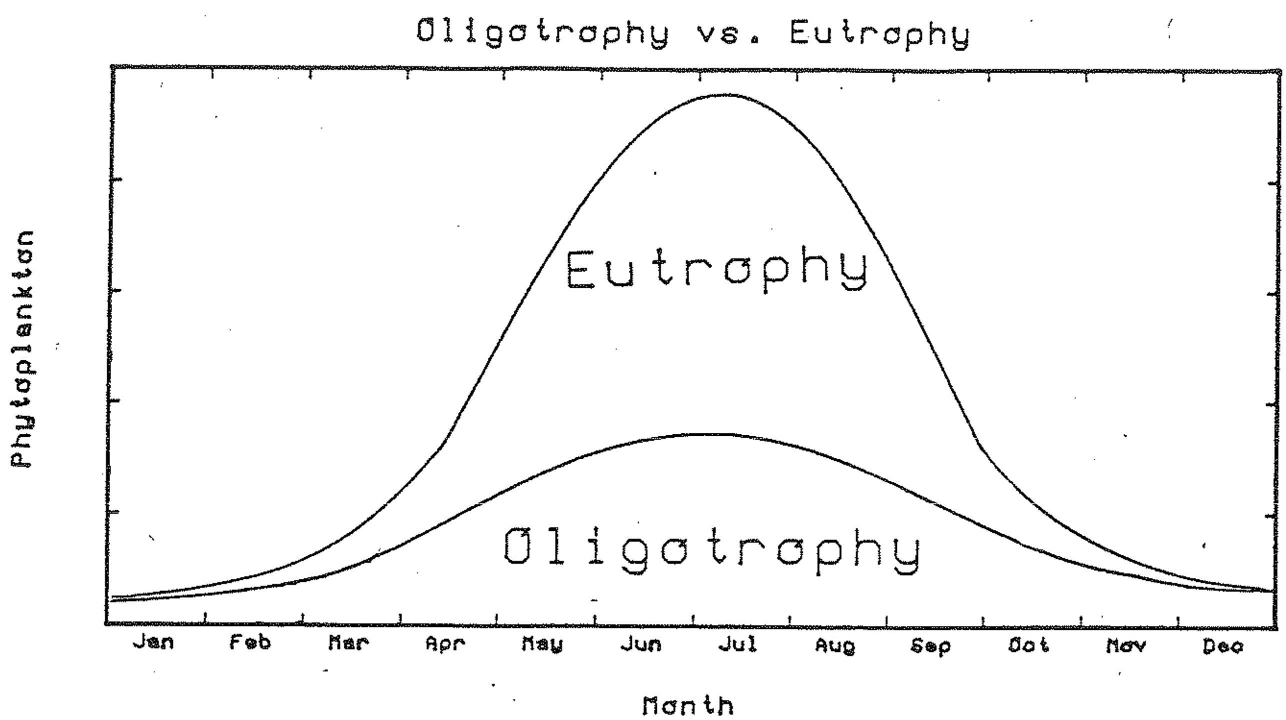

Figure B-2. Variation in phytoplankton through the year. Such variation affects seasonal changes in secchi disk depth, chlorophyll a, and total phosphorus. The variation also affects seasonal distribution of zooplankton.

Two additional major categories of lakes are dystrophy and mixotrophy. Lakes in these two categories have a high concentration of humic acids, and thus are heavily stained. Light penetration is severely restricted by the tea-colored stain, and only the red portion of sunlight is transmitted beneath the surface. Therefore, microscopic algae can grow only near the surface, and even then are light-limited (little or no blue light is transmitted to them). If such a lake has a low concentration of microscopic algae -- indicated both by algal counts (with a microscope) and by a low chlorophyll a concentration, the lake is called dystrophic. It is probable that the lake has a low input (loading) of nutrients, so that the microscopic algae are limited both by low light level and by low nutrient levels. However, if the lake receives a large loading of fertilizer, supplying an abundance of phosphorus, nitrogen and other essential nutrients, the microscopic algae may form a relatively concentrated community, and thus the chlorophyll a concentration rises. Such a lake is called mixotrophic -- a 'mixture' of organisms produced within the lake with imported organic material (mainly humic substances) from bogs or other sources outside the lake basin.

Plankton

Microscopic organisms found throughout the water column of lakes belong to the plankton, or plankton community. Members of the community are especially adapted for life in the open water where they must be able to resist gravity to stay in suspension, and to capture energy for survival. Important members of the plankton community are all microscopic, and belong to several different groups of bacteria, algae, fungi, and animals. In some cases the organisms spend their entire life in the open water, while in other cases only a fraction of their life (usually early stages, as in many insects). Students of biology are often attracted to the plankton community because of the immense diversity of organisms and processes that occur within it, because of its relative importance to a body of water, and especially because much about life of larger organisms can be learned from these special planktonic organisms.

Interactions between the plankton community and lakewater determine to a very large extent the trophic status of lakes. In addition, a firm foundation is laid for the long-term management of lakes when the characteristics of the plankton community and the lakewater are determined. Seasonal changes in both the planktors (members of the plankton community) and in the water chemistry require that several observations be made each year in a lake. Annual changes are generally slower, and can be discerned only during the course of long-term monitoring of principal parameters of plankton and water chemistry.

It is beyond the scope of this section of the report to describe all of the important changes that occur in the plankton as a lake passes through various trophic stages (oligotrophy, mesotrophy, etc.). But foremost among these is the change in concentration of plankton organisms -- especially the microscopic algae. This change is usually regulated by chemical loading into lakes, but is also regulated by seasonal changes in weather, and by several biological processes that occur in lakes -- such as grazing by microscopic crustaceans (water fleas and their allies). A good monitoring program includes not only an analysis of numbers of planktors, but also of types. Predictions of trophic evolution in lakes may be discerned more quickly by observing such changes in the plankton.

The Food Chain System

The maintenance of communities is dependent to a great extent upon food relationships and energy flow. These involve interactions between both the community and the environment. Major communities found in unpolluted 'natural' ponds and lakes are essentially self-sustaining. That is, given energy from the sun and organisms acting the roles of producers, consumers and decomposers, the communities cycle through the seasons each year at levels governed by the natural nutrient supplies and temperature/light regime of the physical system. Only when stress is applied to lakes -- such as insensitive development of shorelines, or poor management of septic or storm drainage -- does the status of the community interaction change. At that point populations grow or fail to grow disproportionately to previous years, and the entire complexion of the lake may change, usually toward a 'degraded' water quality when human activity is the cause of stress.

The fundamental operation in community metabolism, therefore, rests upon the roles which organisms perform at different nutritional or feeding levels, in maintaining transfer of food energy through a series of organisms (Fig. B-3). The roles may be classified as follows:

1. Primary producers or phytoplankton -- microscopic organisms capable of producing plant material through the use of sunlight and nutrients. The organisms in this community form the base of the food chain. Common examples include diatoms, golden algae, euglenoids, dinoflagellates and many more. The concentration of algae is in the range of hundreds of thousands of organisms per liter in oligotrophic lakes, and tens of millions per liter in eutrophic lakes. Also, the diversity of primary producers is large -- hundreds of species may be present in the planktonic community of a single lake.

2. Primary consumers or herbivorous zooplankton -- microscopic 'grazer' organisms that depend upon phytoplankton and bacteria as a food source. The 'grazers' collect their food with an intricate filtering system, and ingest the compacted particles. Common examples of 'grazers' are *Daphnia*, *Cyclops*, *Bosmina* and *Kellicottia*. The grazer community generally includes from five to ten species in a lake, at a concentration of from 1 - 10 organisms per liter in oligotrophic lakes, and more than 100 per liter in eutrophic lakes.

3. Secondary consumer or carnivorous zooplankton -- microscopic organisms that mostly feed upon other zooplankton. Examples include *Chaoborus*, *Polyphemus*, and *Leptodora*. The carnivorous zooplankton community usually include only 1 - 5 species in a given lake, and fewer than 1 organism per liter in oligotrophic lakes or greater than 10 per liter in eutrophic lakes.

4. Tertiary consumers -- young fish of most species as well as minnow species form the community of tertiary consumers. The food source of the community includes mainly the larger species of zooplankton. Examples of fish that remain 'planktivores' even at maturity include the black-nosed dace and pumpkinseed. Populations of tertiary consumers are often small and distributed around the shoreline of lakes. Their concentration is too small to be measured per liter.

5. Top carnivores -- large predatory fish that feed mainly on the smaller fish. There are generally very few large fish in the food chain. Examples include chain pickerel and small-mouth bass.

In reality, the energy interactions within the living communities of lake systems are much more complex than presented above. Many organisms are may be photosynthetic at some times and saprophytic at other times, some are omnivorous, and others switch diets as food supplies change. The efficiency with which energy flows through the food chain varies with the system. In general, more than 90% of the energy acquired by one level is lost as heat, leaving less than 10% for growth and reproduction.

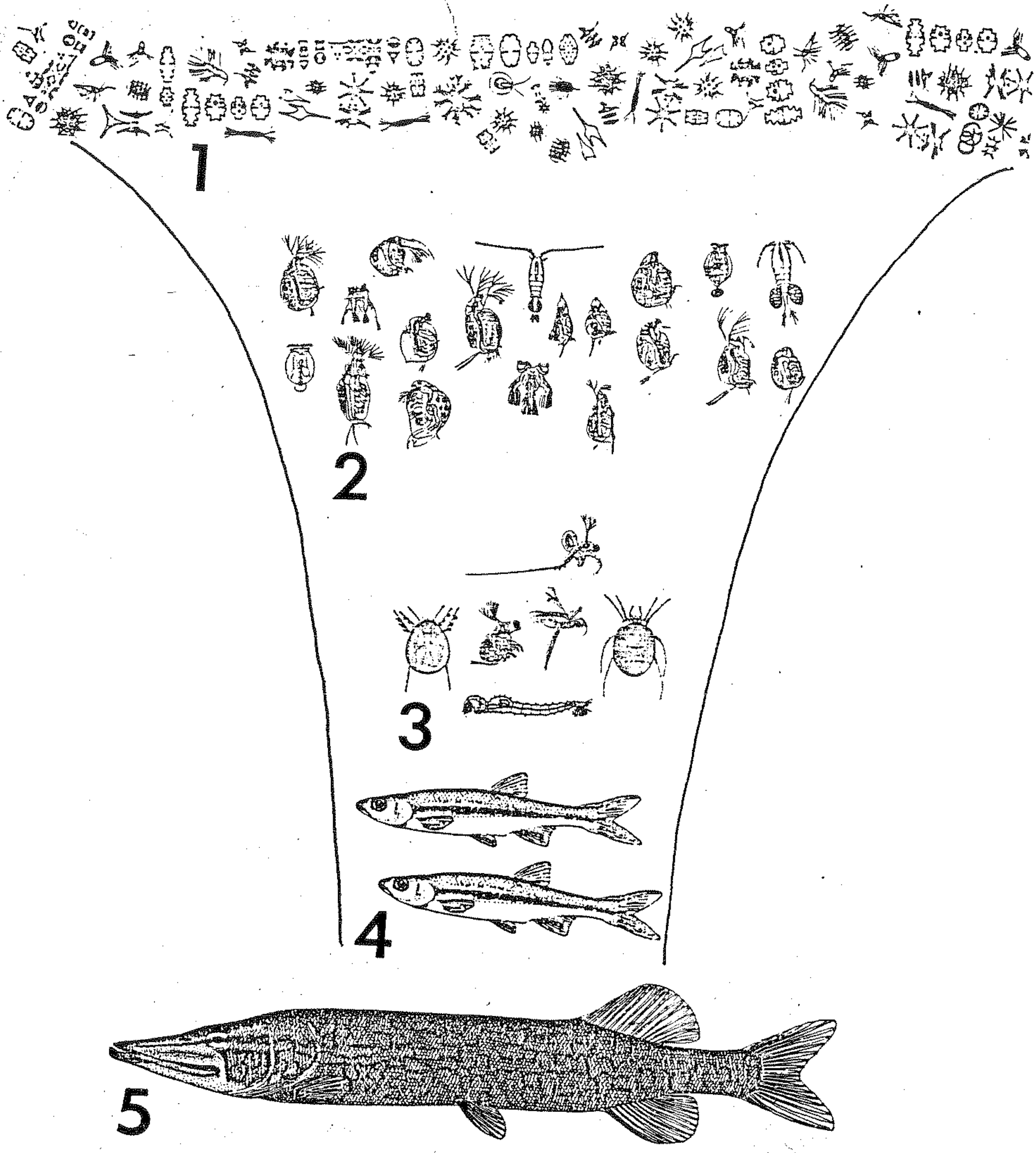

Fig. B-3. A diagramatic representation of food and and energy flow in a freshwater lake. The flow of energy is downward. Note: Organisms not to scale.

GLOSSARY

Aerobe Organisms requiring oxygen for life. All animals, most algae and some bacteria require oxygen for respiration.

Algae See phytoplankton.

Alkalinity Total concentration of bicarbonate and hydroxide ions (in most lakes).

Anaerobe Organisms not requiring oxygen for life. Some algae and many bacteria are able to respire or ferment without using oxygen.

Anoxic A system lacking oxygen, therefore incapable of supporting the most common kind of biological respiration, or of supporting oxygen-demanding chemical reactions. The deeper waters of a lake may become anoxic if there are many organisms depleting oxygen via respiration, and there is little or no replenishment of oxygen from photosynthesis or from the atmosphere.

Benthic Referring to the bottom sediments.

Bacterioplankton Bacteria adapted to the "open water" or "planktonic" zone of lakes, adapted for many specialized habitats and include groups that can use the sun's energy (phytoplankton), some that can use the energy locked in sulfur or iron, and others that gain energy by decomposing dead material.

Bicarbonate The most important ion (chemical) involved in the buffering system of New Hampshire lakes.

Buffering The capacity of lakewater to absorb acid with a minimal change in the pH. In New Hampshire the main chemical responsible for buffering is the bicarbonate ion. (See pH.)

Chloride One of the components of salts dissolved in lakewater. Generally the most abundant ion in New Hampshire lakewater, it may be used as an indicator of raw sewage or of road salt.

Chlorophyll a The main green pigment in plants. The concentration of chlorophyll a in lakewater is often used as an indicator of algal abundance.

Circulation The period during spring and fall when the combination of low water temperature and wind cause the water column to mix freely over its entire depth.

Density The weight per volume of a substance. The more dense an object, the heavier it feels. Low-density liquids will float on higher-density liquids.

Dimictic The thermal pattern of lakes where the lake circulates, or mixes, twice a year. Other patterns such as polymictic (many periods of circulation per year) are uncommon in New Hampshire. (See also meromictic and holomictic).

Dystrophy The lake trophic state in which the lakewater is highly stained with humic acids (reddish brown or yellow stain) and has low productivity. Chlorophyll a concentration may be low or high.

Epilimnion The uppermost layer of water during periods of thermal stratification. (See lake diagram).

Eutrophy The lake trophic state in which algal production is high. Associated with eutrophy is low Secchi disk depth, high chlorophyll a, and high total phosphorus. From an esthetic viewpoint these lakes are "bad" because water clarity is low, aquatic plants are often found in abundance, and cold-water fish such as trout and salmon are usually not present. A good aspect of eutrophic lakes is their high productivity in terms of warm-water fish such as bass, pickerel, and perch.

Free CO2 Carbon dioxide that is not combined chemically with lakewater or any other substances. It is produced by respiration, and is used by plants and bacteria for photosynthesis.

Holomixis The condition where the entire lake is free to circulate during periods of overturn. (See meromixis.)

Humic acids Dissolved organic compounds released from decomposition of plant leaves and stems. Humic acids are red, brown, or yellow in color and are present in nearly all lakes in New Hampshire. Humic acids are comsumed only by fungi, and thus are relatively resistant to biological decomposition.

Hydrogen ion The 'acid' ion, present in small amounts even in distilled water, but contributed to rainwater by atmospheric processes, to groundwater by soils, and to lakewater by biological organisms and sediments. The active component of 'acid rain'. See also 'pH', the symbolic value inversely and exponentially related to the hydrogen ion.

Hypolimnion The deepest layer of lakewater during periods of thermal stratifiction. (See lake diagram)

Lake Any "inland" body of relatively "standing" water. Includes many synonyms such as ponds, tarns, lochs, billabongs, bogs, marshes, etc.

Lake morphology The shape and size of a lake and its basin.

Meromixis The condition where the entire lake fails to circulate to its deepest point; caused by a high concentration of salt in the deeper waters, and by peculiar landscapes (small deep lakes surrounded by hills and/or forests. (Contrast holomixis.)

Mesotrophy The lake trophic state intermediate between oligotrophy and eutrophy. Algal production is moderate, and chlorophyll a, secchi disk depth, and total phosphorus are also moderate. These lakes are esthetically 'fair' but not as good as oligotrophic lakes.

Metalimnion The 'middle' layer of the lake during periods of summer thermal stratification. Usually defined as the region where the water temperature changes at least one degree Celsius per meter depth. Also called the thermocline.

Mixis Periods of lakewater mixing or circulation.

Mixotrophy The lake condition where the water is highly stained with humic acids, but algal production and chlorophyll a values are also high.

Oligotrophy The lake trophic state where algal production is low, Secchi disk depth is deep, and chlorophyll a and total phosphorus are low. Esthetically these lakes are the "best" because they are clear and have a minimum of algae and aquatic plants. Deep oligotrophic lakes can usually support cold-water fish such as lake trout and land-locked salmon.

Overturn See circulation or mixis.

pH — A measure of the hydrogen ion concentration of a liquid. For every decrease of 1 pH unit, the hydrogen ion concentration increases 10 times. Symbolically, the pH value is the 'negative logarithm' of the hydrogen ion concentration. For example, a pH of 5 represents a hydrogen ion concentration of 10^{-5} molar. [Please thank the chemists for this lovely symbolism -- and ask them to explain it in lay terms!] In any event, the higher the pH value the lower the hydrogen ion concentration. The range is 0 to 14.

Photosynthesis — The process by which plants convert the inorganic substance carbon dioxide into organic glucose (sugar) using sunlight as the energy source. Glucose is an energy source for growth, reproduction, and maintenance of almost all life forms.

Phytoplankton — Microscopic algae which are suspended in the 'open water' zone of lakes and ponds. A major source of food for zooplankton. Common examples include: diatoms, euglenoids, dinoflagellates, and many others. Usually included are the blue-green bacteria.

Parts per million — Also known as PPM. This is a method of expressing the amount of one substance (solute) dissolved in another (solvent). For example, a solution with 10 PPM of oxygen has 10 pounds of oxygen for every 999,990 pounds (500 tons) of water. Domestic sewage usually contains from 2 to 10 ppm phosphorus.

Parts per billion — Also known as ppb. This is only 1/1000 of ppm, therefore much less concentrated. As little as 1 ppb of phosphorus will sustain growth of algae. As little as 10 ppb phosphorus will cause algal blooms! Think of the ratio as 1 milligram (1/28000 of an ounce) of phosphorus in 25 barrels of water (55 gallon drums)! Or, 1 gallon of septic waste diluted into 10,000 gallons of lakewater. It adds up fast!

Plankton — Community of microorganisms that live suspended in the water column, not attached to the bottom sediments or aquatic plants. See also 'bacterioplankton' (bacteria), 'phytoplankton' (algae) and 'zooplankton' (microcrustaceans and rotifers).

Saturated When a solute (such as water) has dissolved all of a substance that it can. For example, if you add table salt to water, a point is reached where any additional salt fails to dissolve. The water is then said to be saturated with table salt. In lakewater, gaseous oxygen can dissolve, but eventually the water becomes saturated with oxygen if exposed sufficiently long to the atmosphere or another source of oxygen.

Specific conductivity A measure of the amount of salt present in lakewater. As the salt concentration increases, so does the specific conductivity (electrical conductivity).

Stratum A layer or a "blanket". Can be used to refer to one of the major layers of lakewater such as the epilimnion, or to any layers of organisms or chemicals that may be present in a lake.

Thermal Stratification The process by which layers are built up in the lake due to heating by the sun and partial mixing by wind. (See Appendix B.)

Thermocline Region of temperature change. (See metalimnion.)

Total Phosphorus A measure of the concentration of phosphorus in lakewater. Includes both free forms (dissolved), and chemically combined form (as in living tissue, or in dead but suspended organisms).

Trophic status A classification system placing lakes into similar groups according to their amount of algal production. (See Oligotrophy, Mesotrophy, Eutrophy, Mixotrophy, and Dystrophy for definitions of the major categories, and Appendix B)

Z A symbol used by limnologists as an abbreviation for <u>depth</u>.

Zooplankton Microscopic animals in the planktonic community. Some are called 'water fleas', but most are known by their scientific names. Scientific names include: <u>Daphnia</u>, <u>Cyclops</u>, <u>Bosmina</u>, and <u>Kellicottia</u>.